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14. ABSTRACT
The increasingly complex environment of the 21st century demands unprecedented knowledge, skills and abilities for people from all walks of life. One powerful solution that blends the science of learning with the technological advances of computing is Virtual Environments. In the United States alone, the Department of Defense has invested billions of dollars over the past decade to make this field and its developments as effective as possible. This 3-volume work provides comprehensive coverage of the many different domains that must be integrated for Virtual Environments to fully provide effective training and education. Vol 3, Chapter 8, describes a form of virtual environment training, distributed mission operations (DMO), that has provided the United States Air Force (USAF) with an effective method for training required new skills and competencies. While the focus in this chapter is on use of DMO principles in USAF training, the authors point out that distributed virtual environments for training are being used by all U.S. serices and coalition forces to increase readiness.

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Chapter 8

A VIRTUAL ENVIRONMENT APPLICATION: DISTRIBUTED MISSION OPERATIONS

Dee Andrews and Herbert Bell

U.S. AIR FORCE TRAINING AND OPERATIONAL CHALLENGES[1]

Operation Enduring Freedom and Operation Iraqi Freedom have shown clearly that military forces must remain flexible as they conduct new types of warfare. In Iraqi Freedom, after the first phase of the war, it became clear that the advantage allied troops held in maneuver warfare was greatly affected by the type of insurgent tactics used by the enemy. Fresh approaches to training assure that coalition forces can optimally adapt to new battle conditions. Virtual environments provide some of the new approaches to training required. This chapter describes a form of virtual environment training, distributed mission operations (DMO), that has provided the United States Air Force (USAF) with an effective method for training required new skills and competencies. While our focus will be on the use of DMO principles in USAF training, it is important to point out that distributed virtual environments for training are being used by all U.S. services and, indeed, by all coalition forces to increase readiness.

Current U.S. Air Force warfighter training and operational needs are driven by a number of different factors. There are increased operations and constant deployments as the United States fights wars in a number of countries and conducts both wartime and peacetime missions in many more (Andrews, 2001). These increases in operations not only put strain on personnel and equipment, but they decrease training opportunities because personnel are engaged in real world missions. They also take warfighters away from many training resources at their home bases. In addition, the increased operations tempos put more hours on aging equipment (some airframes are being flown by the grandchildren of the original aircrews), and there is a desire to limit training time on these equipment

[1]The opinions expressed in this chapter are those of the authors and do not necessarily represent the official views of the Department of the Air Force or the Department of Defense.

sets. Also, there is growing pressure on training ranges due to population growth, environmental concerns, and competition for airspace. These pressures make it more difficult to expand training ranges that exist and even to maintain the training range areas that currently exist. Increasing fuel costs have caused decision makers to seek less expensive ways to train than in the actual equipment at least part of the time. At the same time these constraints are being felt, the need for better and more frequent training has speeded up as complex, perishable skills have increased and the need for refresher training accelerates. Finally, USAF senior management would like to use current modeling and simulation technology to break down organizational "stovepipes" that prevent different U.S. Air Force organizations from training and operating with organizations in other Departments of Defense and coalition allies.

DISTRIBUTED MISSION OPERATIONS

The Air Force Research Laboratory developed a construct, and attendant methods and technologies, called distributed mission training (DMT), that has helped the USAF to overcome many of the problems discussed above (Grant, Greschke, Raspotnik & Mayo, 2002). After DMT showed its capability to solve those training problems, senior USAF management determined that the DMT construct could also be used to improve actual operations and the term distributed mission operations was coined. DMO connects live, virtual, and constructive environments to form a synthetic battle space for training and for operations. DMO helps break down stovepipes between military units so they can have better communication and understanding of how best to work together.

DMO TECHNOLOGIES

A DMO links virtual and constructive technologies with live equipment (for example, actual aircraft) via interconnection technologies. Virtual technologies include human-in-the-loop, immersive capabilities, such as flight simulators. Constructive technologies include computer-generated entities and wargames.

The goal is to allow USAF warfighters to train as they intend to fight. This imposes performance requirements on participating simulators. For example, if the time required to send information from one simulator to another is too long, simulator performance may appear unrealistic and may negatively impact training effectiveness. Therefore, a performance goal is to keep the transmission delays between simulators to 100 ms or less.

DMO technologies include communication technologies for brief/debrief of the missions. These include typical video and telephonic devices, as well as electronic whiteboards that allow instructors and trainees to transmit photos, PowerPoint slides, and maps. A key feature of the electronic whiteboards is the capability for instructors or trainees to immediately communicate with all other participants on the network. Experience has shown that because DMO participants may well have never worked together before, any means by which they

can rapidly develop a shared mental model that builds the trust necessary for effective teamwork (Crane, 1999). It is also very helpful to capture data as the exercise unfolds so the entire exercise can be played back for the trainees after the exercise is finished. Freeze features and the capability to replay the exercise at slower or faster speeds also are very helpful (Bennett., Schreiber, & Andrews, 2002).

DMO technology improves the capability to measure training performance in two ways. The first involves capturing objective data by embedding measurement technologies in the computers that run the DMO exercises. These measurement capabilities allow digital data to be captured from fast-moving training exercises as they happen. Second, measurement technologies that allow instructors and observers to record subjective data in real time can be invaluable in helping to highlight key performance failures during the debriefing and later for analysis (Schreiber, Carolan, MacMillian, & Sidor, 2002; Rowe, Schvaneveldt, & Bennett, 2007).

It is important to again note that all of the technologies and methods that make DMO viable for training can also be applied to operational purposes. The USAF believes that eventually these technologies will be used to carry out operational missions. So, in many cases the human-in-the-loop equipment, although installed in a building, could be used not only to train warfighters, but also to let them perform their missions on the same suite of equipment. While embedded training (providing training exercises on operational consoles) has been used for some time, DMOs would now allow that concept to include exercises even for equipment not tethered to a fixed facility. For example, as unmanned aerial systems (UAS) have been introduced into the inventory, they are now flown over the operational theater half way around the world by operators in fixed sites who can use their control consoles to both train and operate.

DMO METHODS AND ISSUES

When warfighters first start to use a DMO capability, they have a tendency to revert to the same training methods that they are accustomed to using on a live training range. While DMO can make use of those training methods, trainees soon learn that DMO can support additional methods that can provide better learning and learning retention. A few examples include the following:

- DMO can allow for exercises to be frozen in midflight so that points can be made by the instructor and errors corrected before they become reinforced;
- DMO provide real time kill removal capability, which means that synthetic and human-in-the-loop entities can be taken out of the scenario as soon as they become casualties. This has an important learning benefit because it means that trainees will not spend time worrying about entities that are no longer germane to the training exercise. Currently, when an aircrew is informed by a range controller that it has been hit, the aircrew flies the aircraft to a "regenerate" zone, from which it is then allowed to come back into the exercise. However, while it is transiting to the regenerate area, it may be mistaken for an active player by aircrews that do not know it has already

become a casualty. In that case, it may be attacked again, which takes the trainees who do the attacking away from a part of the exercise that is still active and relevant.

- DMO allow exercises to be flown so that an aircraft that is hit does not suffer real time kill removal. That is, the aircrew in that aircraft is allowed to keep flying in the exercise, but it is signaled that the aircraft has been hit (usually by flashing the out-the-window displays red) and the aircrew continues to fly. This feature is used when an instructor believes it would harm the integrity of a multiteam exercise to take out one of the aircraft early in an exercise. This condition is often referred to as "shields up."
- Because of the digital nature of DMO exercises, the same conditions for exercises can be re-created over and over again. In training range exercises it is very difficult to re-create exact conditions, and therefore it is difficult to measure progress from one exercise to the next.

A key issue that affects DMO training is the need to have a training strategy that systematically trains new concepts and measures results, rather than merely a practice strategy. This problem plagues all simulator based training, but is particularly pronounced in DMO because DMO may have a live component (Andrews, 1988). When the "practice strategy" is used, the general feeling is that all the instructors have to do is set up a realistic scenario with high fidelity entities and let the trainees fight in the way they normally would in an actual operation (Allesi, 1989). There is no doubt that such practice exercises do produce some learning in a discovery mode; however, the learning is generally haphazard, unsystematic, and unpredictable. DMO instructors who instead follow the instructional system development approach in developing the training exercises find that considerably more learning takes place when training is designed and conducted in that mode (Rothwel and Kazanas, 2003). Prerequisite skills should be defined before the training starts, and then clear training objectives must be stated based upon training requirements. Using this front-end analysis, the scenarios then are planned with appropriate measurement of process and product stated. Trainees should be given time to familiarize themselves with the simulators and constructive models before the exercise begins again. Then, and only then, should the actual training exercise start. Instructors must decide beforehand about the following issues: whether or not freeze will be used ("freeze" refers to the strategy of stopping the scenario at certain points for instructional purposes), if and how new entities will be introduced once the exercise is under way, and whether real time kill removal will be used. Significant DMO experience has shown that these systematic steps are crucial to the instructional effectiveness of the training exercise.

DMO EVALUATION

Evaluating the effectiveness of DMO is a complex undertaking. Metrics are necessary for assessing the trainees' process as well as mission effectiveness on the actual battlefield (Bell, Bennett, Denning & Landrum, 2003). Such DMO evaluations follow many of the same procedures and use many of the same

process and product measures as are used when training is delivered in non-DMO modes. These include process and product metrics such as number and types of communications between teammates, degree of coordination, accuracy of situational assessments, correctness of command and control decisions, and impact of the mission's effects on the simulated battlefield (Schvaneveldt, Tucker, Castillo, & Bennett, 2001).

In addition to the evaluation of trainee and operator actions in the DMO environment, technologists can also measure the effectiveness of the technology in providing a realistic synthetic battle space. Examples include the following:

- **Interdevice transport delay**—How long does it take for an output of one DMO device to be distributed to other nodes on the DMO network?
- **Adequacy of communication quality over the DMO network**—This is typically measured subjectively by instructors who are listening to the DMO exercise. The criteria for measuring quality of communications have to do with the type of communication, the actual message, and the timeliness and completeness of the message.
- **Network security**—Is the DMO network protected from external intrusions? Is the network protected from internal intrusions; that is, can all the sites inside the DMO network be sure that other sites inside the network do not intrude into parts of their computer complex for which they do not have authorization?
- **Mission planning**—Can the warfighters who are planning the missions access and send relevant information in a time frame consistent with the mission requirements? What is the quality of the missions that are planned?

IMPACT OF DMO VIRTUAL ENVIRONMENTS

Training

The DMO construct has had a considerable positive impact on USAF training. In addition, over the years that impact has spread to the other U.S. military services and to coalition allies. DMOs are used in many of the air force's major commands, including Space Command, Air Mobility Command, and Special Operations Command. To provide an example of how DMO works in the U.S. Air Force, we now examine briefly DMO use in the Air Combat Command.

The Air Combat Command has installed "mission training centers" (MTCs) at many of its fighter bases. These MTCs consist of two- or four-flight simulators and attendant instructional support systems. The simulators have wraparound domes with out-the-window 360° visual scenes. The cockpits have high physical and high functional fidelity. The trainees can fly as a two- or four-ship formation just as they do in the real world. The MTC can be linked to other simulation centers that might simulate command and control platforms, U.S. Army or Navy units, or coalition partners.

Training exercises can include air-to-air and air-to-surface missions. The DMO simulators can be used to provide a range of training opportunities for the warfighters: individual procedural training, two-ship or four-ship element level team training, as well as team of teams training with other DMO sites including

coalition partners. Instructors are provided an instructor/operator station that allows them to view the formation from a "God's eye view," as well as the entire mission evolution. In addition, they can see what the trainees are seeing out of their front windscreens. They hear all communication between the pilots and other entities on the network. When the exercise is completed, the trainees can debrief, as was described above, by replaying the data from the exercise. The trainees or instructor can stop and start the exercise debrief as needed.

Operations

The full DMO concept has not yet been realized in operations. Perhaps the best current application is in mission rehearsal. In mission rehearsal, various DMO entities can be linked to create a synthetic mission environment that closely mimics the environment the warfighters will be encountering when they perform their mission. Terrain, cultural features, humans, weather, threat effects, and many other elements can be highly modeled to present a very close approximation to what the warfighters will see when conducting the mission. As mentioned above, a good example of this principle is the operation of a UAS over a battlefield while its operator is many thousands of miles away at a control station. The difference between the UAS control station as an operational control device versus a training simulator is difficult to differentiate physically; only in purpose do we see differences, those differences of purpose being actual operational control versus training.

FUTURE OF DMOS

The DMO concept has been adopted (often with different names) across the DoD and in many allied countries. We expect increased use of DMO technologies and methods as budgets become tighter, the military seeks to relieve stress on personnel, mission deployment training needs increase, and alliances increase in size and complexity. These four factors are explained in more detail below.

DMOs can provide significant cost savings for both training and operations. Current fuel costs and wear and tear on actual equipment can make flying even a one-ship training mission very expensive. When the costs are combined to train entire multiplayer exercises, the costs can easily be in the millions of dollars for a large exercise. DMO allow the trainees to train in relatively inexpensive-to-operate simulators and constructive models as opposed to actual equipment. Orlansky and Chatelier (1983) provide an excellent framework for determining the cost-effectiveness of single simulators for training. It is believed that that model can be used to determine the cost-effectiveness for DMOs. While the DMO concept allows for live equipment entities (for example, aircraft) to be part of DMO exercises, it is expected that their role will become more limited in the DMO future as simulators and constructive models improve. Having said that, it is important to note that there will always be a place for live equipment in those exercises. DMO is expected to allow simulators and constructive models to be

used more and more in actual operations as supports and/or replacements for some actual equipment. That will potentially save lives.

Since the end of the Cold War, coalition forces have deployed at a much greater frequency because many of the forward-deployed bases used in the Cold War were closed. That means that the warfighters are generally away from home base more often than before. Not only does this frequency of deployment affect the warfighters' personal and family lives, but this makes it much more difficult to meet their training goals. Therefore, the training they do get at home must be as effective as possible with high skill retention. DMO technologies can assist in increasing the effectiveness of training time they do get. In addition, DMO assets are becoming more deployable and will be going with the warfighters to their deployed bases more often.

Warfighters will rely more and more on DMO to help them prepare for and carry out missions. Mission rehearsals at home and in the area of operations will rely increasingly on DMO technologies. These include rapidly updatable databases that will give DMO scenarios remarkable fidelity for the missions that will be conducted. These database updates can include real time weather changes, as well as new threats. Virtual and constructive DMO technologies are used more and more to actually support the mission, including having warfighters conduct their mission at very long distances through the use of weapon systems such as the UAS.

Finally, the U.S. military forces will seldom conduct operations, especially large operations, by themselves anymore, but instead will fight with coalition partners. Obviously, physically bringing together large units from many different countries to train together is limited due to distance and cost. This DMO coalition concept for distributed mission training across countries, continents, and oceans has already been tested, and this approach will become much more widespread in the future. In like manner, entire operations of coalition partners will see the positive impact of DMO as virtual and constructive entities work with live operational equipment in the theater to support the mission (McIntyre and Smith, 2002). For all of these reasons, DMO will be a major factor in future training and operations around the world.

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